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# Abrasion and Deformed Layer Formation of Manganese-Zinc Ferrite in Sliding Contact With Lapping Tapes

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FORMATION OF MANGANESE-ZINC FERRITE IN  
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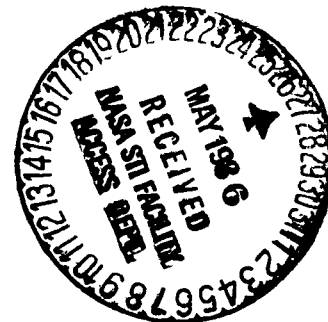
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ABRASION AND DEFORMED LAYER FORMATION OF MANGANESE-ZINC FERRITE IN  
SLIDING CONTACT WITH LAPPING TAPES

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Abstract

Wear experiments were conducted using replication electron microscopy and reflection electron diffraction to study abrasion and the deformed layers produced in single-crystal Mn-Zn ferrite simulated heads during contact with lapping tapes. The crystalline state of the head is changed drastically during the abrasion process. Crystalline states ranging from nearly amorphous to highly textured polycrystalline can be produced on the wear surface of a single-crystal Mn-Zn ferrite head. The total thickness of the deformed layer was approximately 0.8  $\mu\text{m}$ . This thickness increased as the load and abrasive grit size increased. The anisotropic wear of the ferrite was found to be inversely proportional to the hardness of the wear surface. The wear was lower in the order  $\{211\} > \{111\} > \{100\} > \{110\}$ . The wear of the ferrite increased markedly with an increase in sliding velocity and abrasive grit size.

INTRODUCTION

Abrasive impregnated tape, commonly called lapping tape, is used for the final finishing and/or cleaning of the sliding surface of magnetic heads used for in-contact recording applications. Lapping tape rather than magnetic tape

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can be used to screen magnetic head materials and materials for fabricating flanges and parts in magnetic tape guides for computer, audio, or video tape drive systems. Lapping tape can also accelerate wear experiments and reduce the time and cost of experimentation. Despite the critical use of lapping tape in magnetic recording systems, there is a lack of fundamental understanding of abrasiveness and of the abrasion mechanism of the lapping process as well as of the effect of tape abrasion on the structure-sensitive magnetic properties of the magnetic head (1),(2).

The objective of this paper is, therefore, to discuss the wear of and the deformed layer formation in manganese-zinc (Mn-Zn) ferrite heads in sliding contact with various lapping tapes. This investigation also examined the effects of applied load, abrasive grit size, crystallographic orientation, and sliding velocity on the wear of the heads and on the formation of the deformed layer. All the experiments were conducted with simulated heads sliding against a lapping tape at a tape speed of 0.19 m/s in room-temperature air at atmospheric pressure. The simulated heads were substituted for magnetic heads in order to examine tribological properties, such as wear and hardness, and to analyze the wear surface of the ferrite by replication electron microscopy and reflection electron diffraction.

## MATERIALS

The single-crystal Mn-Zn ferrites as-grown crystals were 99.9 percent pure (Table 1). Table 1 presents the compositions of the ferrites and shows hardness data for various crystallographic orientations of the ferrites. The orientations of the single-crystal ferrites were determined by the back-reflection Laue method and are to an accuracy of  $\pm 1^\circ$  for the {100}, {110}, and {111} surfaces and of  $\pm 2^\circ$  for the {211} surfaces. The {110} planes in the  $\langle 100 \rangle$  direction exhibit the greatest Knoop hardness.

The single-crystal Mn-Zn ferrite surfaces were examined by Auger electron spectroscopy (3). The crystals were in the as-polished state. After the crystal surfaces were sputter cleaned with argon ions, the Auger spectra revealed Auger peaks, which indicated the presence of manganese and zinc, as well as oxygen and iron, on the ferrite surfaces. The impurities found in the crystal surfaces were negligible. Thus, the single-crystal Mn-Zn ferrite surfaces were very pure.

The lapping tapes used in this investigation were aluminum oxide (1000- and 2000-mesh  $\text{Al}_2\text{O}_3$ ) and silicon carbide (2000- and 4000-mesh SiC) powders coated on a polyester film backing (thickness,  $23 \pm 1 \mu\text{m}$ ; Young modulus,  $5.8 \times 10^9 \text{ Pa}$ ; and film width, 12.7 mm). The grain size of the abrasive grit was obtained by averaging the measurements of 150 grains from scanning electron micrographs (Table 2).

#### APPARATUS

A modified, commercial two-head helical-scan video-tape recording system capable of measuring the friction and wear of the magnetic heads was used in this investigation (Fig. 1).

Two simulated heads were positioned exactly opposite each other on the drum [Fig. 1(a)]. Measuring microscopes and tape-tension measuring devices were mounted in the apparatus. The wear of the heads and the amount of head displacement from the drum surface [Fig. 1(b)] were measured using the microscopes.

The 12.7-mm-wide lapping tape, which was wound around the drum at a  $190^\circ$  wrap angle, traveled helically at 0.19 m/s at an angle of  $2^\circ 50'$  on the drum surface. The tape tension was controlled by a tension arm, which varied the normal load that was applied to the tape-head contact.

The normal load was also controlled by displacing the heads radially from the drum surface. The applied load and friction force were proportional to



the tape tension and the amount of head displacement up to 150  $\mu\text{m}$ . At displacements above 150  $\mu\text{m}$  the normal load and friction force increased at a rate slightly higher than the displacement rate. The final tape tension was three times greater than the initial tape tension.

#### EXPERIMENTAL PROCEDURE

Experiments were conducted with various lapping tapes in sliding contact with the simulated heads. In these experiments both the head and the tape were in motion; that is, the head rotated at 11 m/s in a direction opposite to that in which the tape traveled at 0.19 m/s. All experiments were conducted in room-temperature laboratory air at a relative humidity of 50 $\pm$ 10 percent.

The wear of the ferrite head due to lapping abrasion was measured by two independent methods (shown schematically in Fig. 2). One method was the Knoop indentation method, which uses the reduction in size of a nonsymmetrical pyramid. Knoop indentations were made on the sliding surface of the simulated ferrite head. The long diagonal lengths of the indentations were measured by a microscope before and after each experiment. Then the volume of material removed ( $\Delta W$ ) was calculated from the reduction in the length of the diagonal:

$$\Delta h = \frac{d_b - d_a}{m} \quad [1]$$

$$\Delta W = \Delta h \cdot A \quad [2]$$

where  $\Delta h$  is a change in thickness,  $d_b$  and  $d_a$  the average of the long diagonal lengths of Knoop indentations before and after lapping abrasion,  $m$  a ratio between the long diagonal length and depth of Knoop indentation, and  $A$  the worn area. It was possible to measure  $\Delta h$  to an accuracy of  $\pm 0.1 \mu\text{m}$ , because the value of  $m$  was constant (30.8) when the Knoop indentation method was used.

For the second method, square pyramid indentations were produced as standard markers on the side of the simulated head by a diamond pyramid

indenter (Vickers) as shown in Fig. 2. The sides were cloth-polished with 1- $\mu\text{m}$  diamond paste, and the resultant surface had irregularities that were less than 0.1  $\mu\text{m}$  in maximum height. The distances between the standard markers and the abraded surface were measured with a measuring microscope. The volume of material removed was, then, estimated by the average distance measured. The wear rate is expressed as the amount of material removed from the head surface (wear depth) per unit distance of sliding.

The first method of measuring wear was generally applied to experiments in which there was a very small amount of material removed from the simulated head; the second method was applied to experiments in which there were relatively greater abrasion conditions.

## RESULTS AND DISCUSSION

### Wear and Deformed Layer Formation With Ferrites

A lapping tape sliding on a Mn-Zn ferrite simulated head generates abrasion and develops a deformed layer on the ferrite surface. The wear of this head is linearly proportional to the sliding distance (Fig. 3).

Figure 4 presents a typical replication electron micrograph and typical diffraction patterns of a Mn-Zn ferrite {110} simulated head after sliding against a 14- $\mu\text{m}$   $\text{Al}_2\text{O}_3$  (1000 mesh) lapping tape. The wear surface of the ferrite shows a large number of plastically deformed grooves which were formed primarily by the plowing and microcutting actions of the abrasive grits held in the lapping tape. The grooves were formed in the lapping direction (sliding direction of the head).

The wear surface has two kinds of typical diffraction patterns: (1) sharp Debye-Scherrer rings containing enlarged streak spots [Fig. 4(b)] and (2) very broad Debye-Scherrer rings with almost no special pattern [Fig. 4(c)]. The electron diffraction patterns obtained from the abraded head surface indicate that the wear surface had crystalline states that ranged from nearly amorphous

(possibly containing fine crystalline grains a few nanometers in diameter) to highly textured polycrystalline.

To further investigate the crystalline state of the surficial layer of the Mn-Zn ferrite head, reflection electron diffraction patterns with depth profiling were obtained from both the wear and etched surfaces. The etching was done with hydrochloric acid at  $50 \pm 1$  °C. The results are presented in Fig. 5.

The arcs in the electron diffraction pattern of the wear surface indicate that highly textured surfaces were formed during sliding [Fig. 5(a)]. The surface of the ferrite head etched to a depth of 0.2  $\mu\text{m}$  from the wear surface has an enlarged streak spot pattern [Fig. 5(b)]. The streaking indicates a great amount of plastic deformation; that is, a highly strained, mosaic single-crystal structure. (The large number of line defects can cause streaking in a diffraction pattern.) The surface etched to a depth of 0.4  $\mu\text{m}$  has a relatively sharp spot pattern without streaking [Fig. 5(c)]. The surface etched to depths of 0.8 and 1.0  $\mu\text{m}$  has Kikuchi lines (pairs of black and white parallel lines), which indicate a bulk crystalline structure containing no mechanical stress [Fig. 5(d) and (e)].

The thickness of the textured, polycrystalline layer is 0.04 to 0.1  $\mu\text{m}$ , that of the highly strained, mosaic single-crystal layer is 0.1 to 0.2  $\mu\text{m}$ , and that of the plastically deformed single-crystal layer is 0.5  $\mu\text{m}$ . Thus, the total thickness of the deformed layer on the Mn-Zn ferrite head presented in Fig. 5 is 0.8  $\mu\text{m}$ .

Figure 6 presents a summary of schematic structures for the deformed layer and an etching rate for the abraded head as a function of the etching depth (distance from the wear surface). This is called an etching-rate depth profile. The most surficial layer, which has a textured, polycrystalline structure, has the highest etching rate. This indicates that it contains the

greatest amount of defects. The etching rate decreases as the etching depth increases. The decreasing etching rate is related to a decrease in the concentration of defects in the crystal. The fewer the defects in the layer, the lower the etching rate.

The amount of wear and the characteristics of the deformed layers depend on applied normal load, abrasive grit size, crystallographic orientation of the ferrite, and sliding velocity. Each of these subjects is discussed subsequently.

#### Effect of Load

The wear of the head was quite linearly proportional to the applied normal load (the apparent contact pressure at the interface) as indicated in Fig. 7. The coefficient of friction, however, was not dependent on the normal load but remained constant.

Figure 8 shows the thickness and crystal structure of the deformed layers produced on the head surfaces as a function of applied normal load. The thickness of the deformed layer, which was determined with reflection electron diffraction by depth profiling, increases as the normal load increases. The increase of the deformed layer with load is due primarily to an increase in the extent of the plastically deformed single-crystal layer [Fig. 8(b)].

The etching rate was also dependent on the amount of normal load applied to the tape-head contact. The etching rate increased as the load increased; that is, the amount of defects in the deformed layer increased with an increase in load.

#### Effect of Abrasive Grit Size

Figure 9 presents the wear rate of and the thickness of the deformed layer for the Mn-Zn ferrite {110} plane of the simulated heads sliding against lapping tapes as a function of abrasive grit size. Wear rate is strongly dependent on abrasive grit size; that is, it increases markedly with an

increase in grit size. Many investigators have found that abrasive wear increases with an increase in the size of the abrasive grit up to a certain critical value and thereafter is independent of grit size (1). The critical grit size (30- to 150- $\mu\text{m}$  diam) depends strongly on the abrasive, the material, the experimental conditions, and the parameters (e.g., load, velocity, and environment). The grit size employed herein for the lapping tape was smaller than 14  $\mu\text{m}$  in average diameter. This is much less than the critical grit size found by many investigators (1). Figure 9(a) clearly indicates that the larger the grit size, the greater the wear rate.

The coefficient of friction, however, is not dependent on the abrasive grit size, but rather on the kind of abrasive grit. The coefficient of friction was approximately 0.4 with  $\text{Al}_2\text{O}_3$ -grit lapping tape but only 0.2 with a SiC-grit lapping tape.

The thickness of the deformed layer, when it was determined with reflection electron diffraction by depth profiling, increased as the abrasive grit size increased. With a 2.7- $\mu\text{m}$  SiC-grit lapping tape the thickness of the deformed layer was 0.5 to 0.6  $\mu\text{m}$ ; with a 14- $\mu\text{m}$   $\text{Al}_2\text{O}_3$ -grit lapping tape the thickness of the deformed layer was 0.8 to 0.9  $\mu\text{m}$ .

The thickness of the deformed layer, when it was determined with etching-rate depth profiling, was also dependent on the abrasive grit size of the lapping tape. Again, thickness increased as abrasive grit size increased.

#### Effect of Crystallographic Orientation and Vickers Hardness

The anisotropic nature of wear and of deformed layer formation for Mn-Zn ferrite surfaces (the {100}, {110}, {111}, and {211} planes) in sliding contact with lapping tapes was examined. First, 14- $\mu\text{m}$   $\text{Al}_2\text{O}_3$  lapping tapes were used. All the wear surfaces of the four crystallographic planes revealed a large number of plastically deformed grooves, similar to those in Fig. 4.

Replication electron micrographs showed no differences among the four wear

surfaces. The diffraction patterns obtained from the four wear surfaces (generally the same as those in Fig. 4.) indicated that all the wear surfaces had crystalline states that ranged from nearly amorphous (having fine grains) to highly textured polycrystalline. Furthermore, the thickness of the deformed layers was not dependent on the crystallographic orientation. The thickness of the deformed layers for the four crystallographic planes sliding against 14- $\mu\text{m}$   $\text{Al}_2\text{O}_3$  lapping tapes was 0.8 to 0.9  $\mu\text{m}$ .

Figure 10 shows the wear depths of four crystallographic planes ( $\{100\}$ ,  $\{110\}$ ,  $\{111\}$ , and  $\{211\}$ ) of a ferrite head sliding against a 7.1- $\mu\text{m}$   $\text{Al}_2\text{O}_3$  lapping tape as a function of Vickers hardness of the wear surfaces. The wear is influenced by the crystallographic orientation and Vickers hardness. The wear of the ferrite surfaces was lower in the order  $\{211\} > \{111\} > \{100\} > \{110\}$ . The slip plane with the most closely packed planes of Mn-Zn ferrite (i.e., the  $\{110\}$ ) exhibits the greatest resistance to abrasion.

Khrushchov and Babichev found that the resistance of metals to abrasive wear is related to their static hardness under two-body conditions; that is, the inverse of the abrasive wear rate is proportional to hardness for a large number of annealed, pure metals (5). Avient, et al., have indicated theoretically and experimentally that the resistance of metals to abrasive wear is inversely proportional to the Vickers hardness of the fully work-hardened surface region of the abraded metal (6). Similar results have been obtained by Rabinowicz, et al., for three-body conditions (7). In Fig. 10 the wear volume is inversely proportional to the Vickers hardness of the wear surface region of the abraded ferrites.

To compare these wear characteristics with those of other materials as a function of hardness, experiments were conducted (in a manner similar to that described earlier) with a 14- $\mu\text{m}$   $\text{Al}_2\text{O}_3$  lapping tape sliding against simulated heads of aluminum, a 4.5-percent silicon/iron alloy, silicate glass, and Mn-Zn

ferrite {110}. (The wear for the materials was again linearly proportional to the sliding distance.) The resistance of the materials to lapping abrasion was linearly related to their Vickers hardness; that is, the inverse of the abrasive wear rate for these materials was proportional to the Vickers hardness of the abraded surface.

#### Effect of Sliding Velocity

Wear experiments were conducted with the {110} plane of the simulated heads sliding against the lapping tapes at sliding velocities up to 11 m/s. The wear rate of the ferrite heads is presented as a function of sliding velocity in Fig. 11. The wear rate, which depends significantly on the sliding velocity, generally increases with an increase in sliding velocity. The wear rate at a sliding velocity of 11 m/s was about three times higher than that at 0.5 m/s. The dependency of wear rate on sliding velocity is believed to be due primarily to a softening of the ferrite surface by frictional heating during the sliding process.

The dynamic and static hardness of the ferrite decrease markedly with temperature (8). The static micro-Vickers hardness of ferrite at room temperature was 1.1 and 1.3 times higher than that at 100 and 300 °C, respectively. The dynamic hardness of ferrite at room temperature was 1.2 and 1.5 times higher than that at 100 and 300 °C, respectively.

In addition to the softening of the ferrite surface as a result of frictional heating at the interface, the frictional heating at the tip of the asperities of abrasive grits locally breaks down the plastic binder coating film of the abrasives. The clean, sharp edges of the asperities, which are very abrasive, then appear on the tape surface and efficiently cut and remove the ferrite from the head surface.

The thickness of the deformed layer, which was determined with electron diffraction by depth profiling, increased very slightly ( $0.1\text{ }\mu\text{m}$ ) as the sliding velocity increased.

Figure 12 presents etching-rate depth profiles for the wear surface of the simulated heads. These wear experiments were conducted at sliding velocities of 11, 3.8, and 0.55 m/s. The wear surface produced at a sliding velocity of 11 m/s gave the highest etching rate, which indicates that it contains the greatest amount of defects. In general, the higher the sliding velocity, the greater the etching rate.

Thus, the wear and deformation of the ferrite heads increase with an increase in the sliding velocity of the tape-ferrite contact.

#### CONCLUSIONS

The following conclusions were drawn from wear experiments using electron microscopy and electron diffraction to study single-crystal Mn-Zn ferrite simulated heads in contact with lapping tapes:

1. Considerable plastic flow occurred on ferrite surfaces and the crystalline state of the wear surfaces of the heads were changed drastically during abrasion. Crystalline states ranging from nearly amorphous (containing fine grains a few nanometers in diameter) to highly textured polycrystalline were produced on the wear surfaces of single-crystal Mn-Zn ferrite heads.

2. The total thickness of the deformed layer of the ferrite heads was approximately  $0.8\text{ }\mu\text{m}$ . Thickness increased as the load and abrasive grit size increased. The dependency of this layer on the crystallographic orientation of the sliding surface and on the sliding velocity of the head was negligible.

3. The wear of the ferrite heads was linearly proportional to the sliding distance and the load. It increased markedly with an increase in abrasive grit size.



4. The anisotropic wear was inversely proportional to the hardness of the wear surface. The wear was lower in the order  $\{211\} > \{111\} > \{100\} > \{1\bar{1}0\}$ .

5. The wear of the ferrite heads increased as the sliding velocity of the heads increased. The wear rate at a sliding velocity of 11 m/s was about three times greater than that at 0.5 m/s.

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TABLE 1. - COMPOSITION AND HARDNESS DATA ON MANGANESE-ZINC FERRITE USED  
FOR SIMULATED HEADS

[Single-crystal Mn-Zn ferrite; composition, wt %:  $\text{Fe}_2\text{O}_3$ , 71.6;  
 $\text{MnO}$ , 17.3;  $\text{ZnO}$ , 11.1.]

Surface Direction	(100) [001]	(100) [011]	(110) [001]	(110) [110]	(111) [112]	(111) [110]	(211) [111]	(211) [011]
Knoop hardness*	630	560	630	560	580	600	550	580
Vickers hardness†	630		645		590		650	

\*Knoop harness measuring load, 3 N.

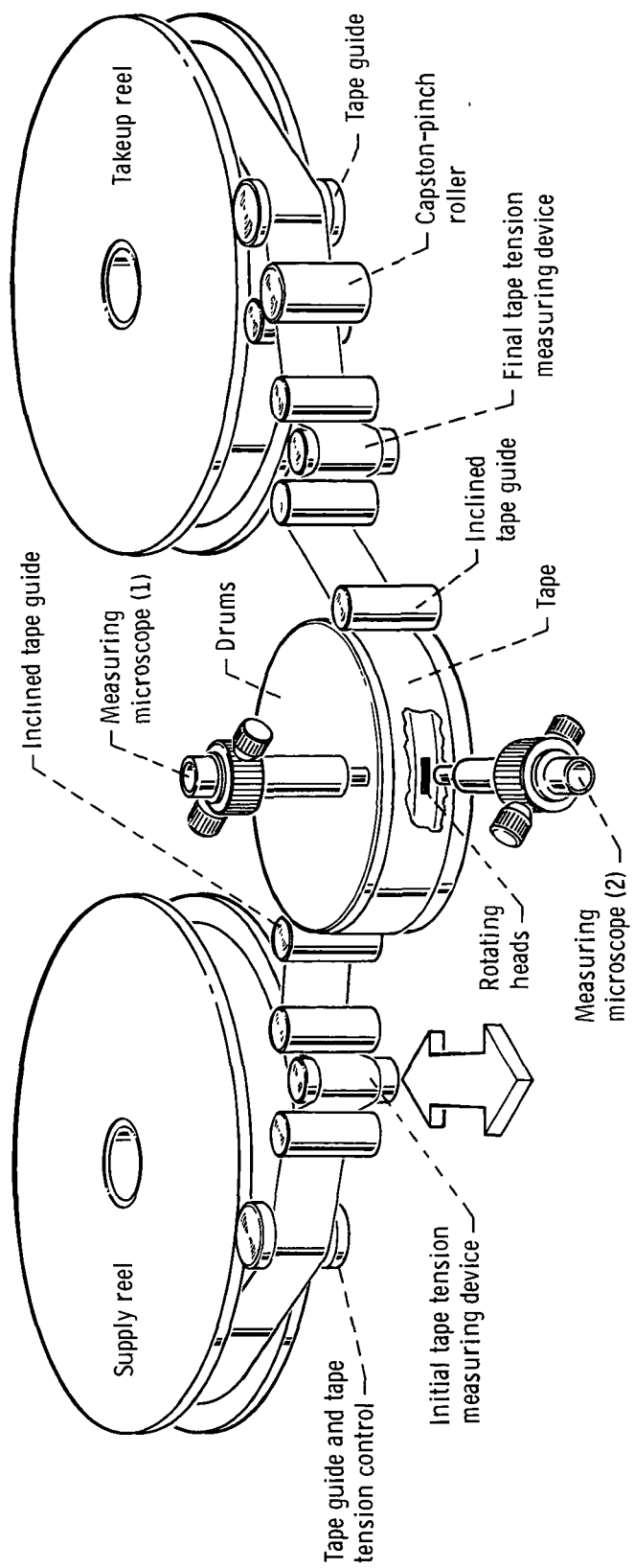
†Vickers hardness measuring load, 0.5 N.

TABLE 2. - LAPPING TAPES AND POLYESTER FILM

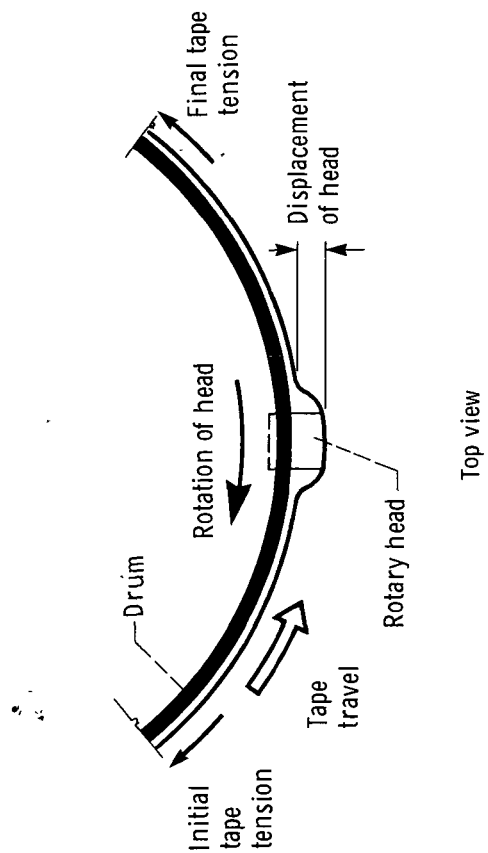
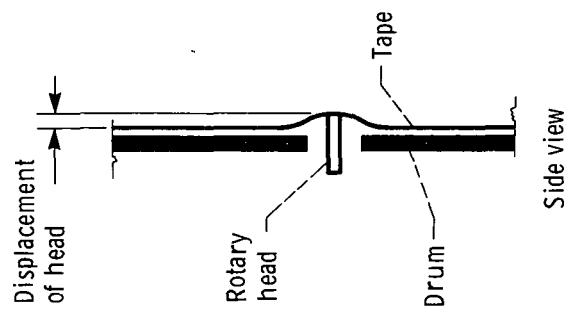
Abrasive powder (mesh)	Average grit size* of abrasive, $\mu\text{m}$	Total tape thickness†, $\mu\text{m}$
$\text{Al}_2\text{O}_3$ (1000)	14	46
$\text{Al}_2\text{O}_3$ (2000)	7.1	47
$\text{SiC}$ (2000)	6.3	42
$\text{SiC}$ (4000)	2.7	46

\*Average grain size was measured from  
scanning electron micrographs.

†Thickness of the polyester film  
backing, 23  $\mu\text{m}$ .

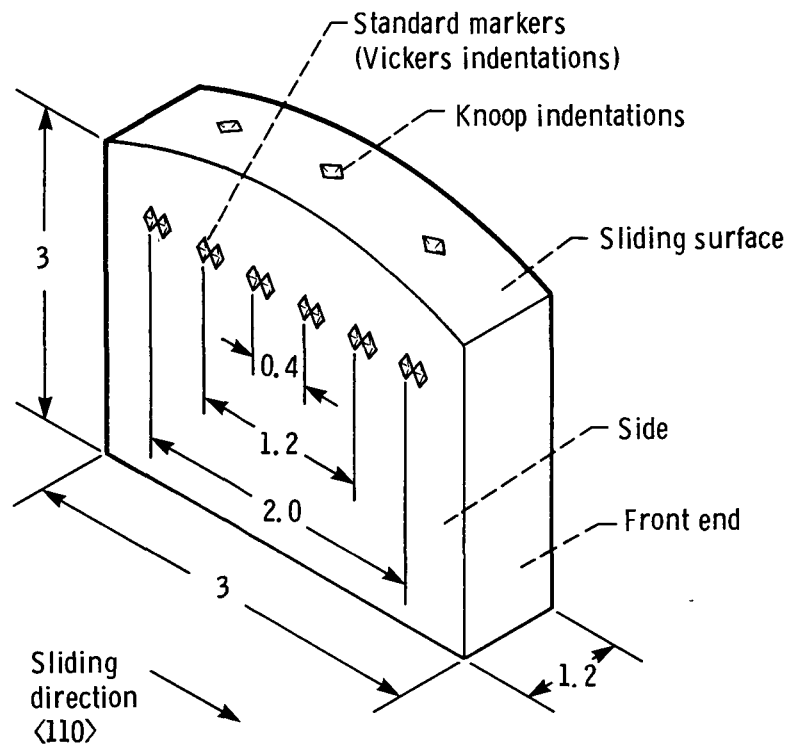


(a) Helical scan recorder.



(b) Configuration of head-to-tape contact.

Figure 1. - Friction and wear apparatus.



CRYSTALLOGRAPHIC PLANE OF SINGLE-  
CRYSTAL SIMULATED HEADS

Sliding surface	End	Side
Nearly (100)	(011)	(0 $\bar{1}$ 1)
Nearly (110)	( $\bar{1}$ 10)	(001)
Nearly (111)	(01 $\bar{1}$ )	( $\bar{2}$ 11)
Nearly (211)	(0 $\bar{1}$ 1)	( $\bar{1}$ 11)

Figure 2. - Simulated heads. All units in mm unless otherwise indicated.

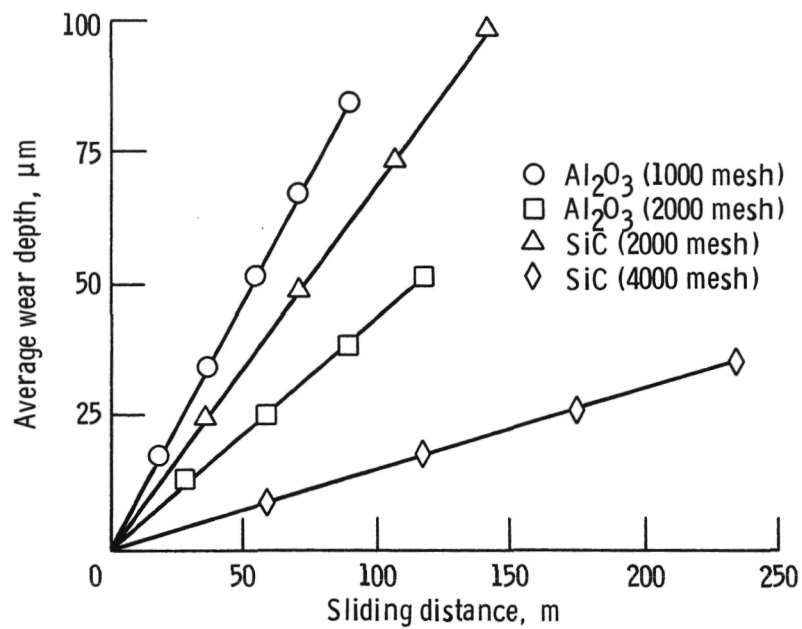
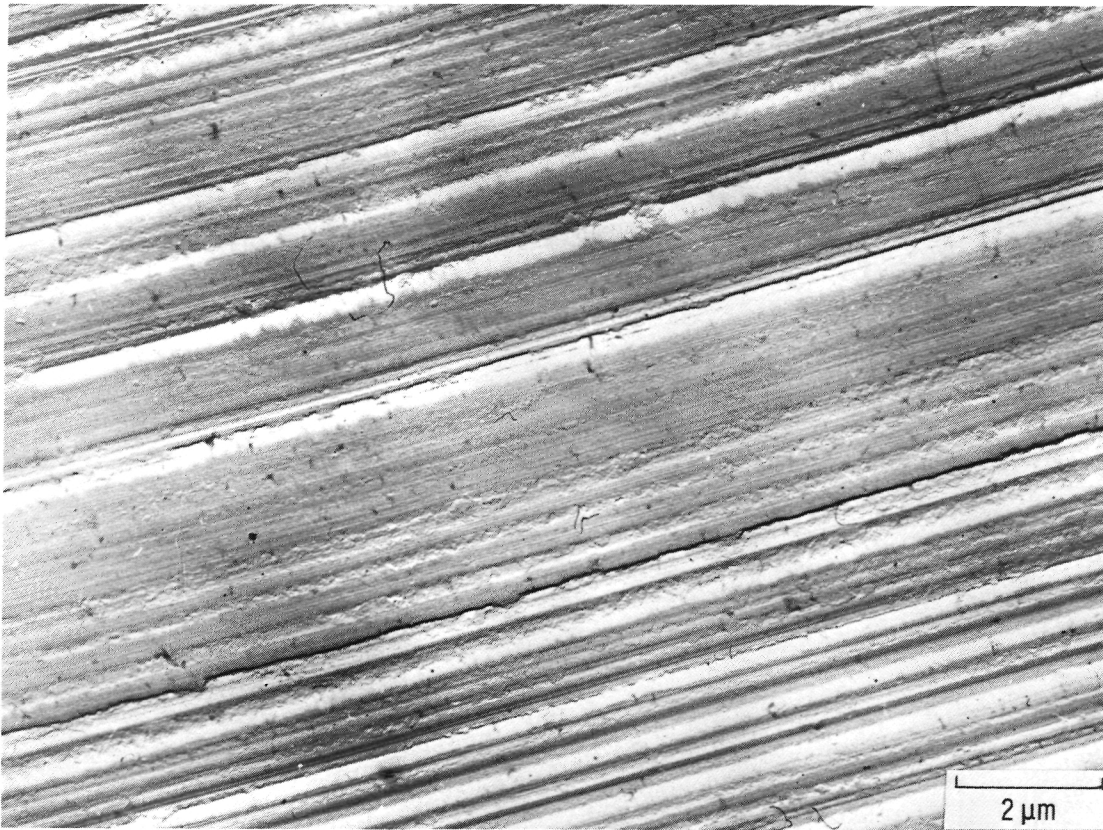
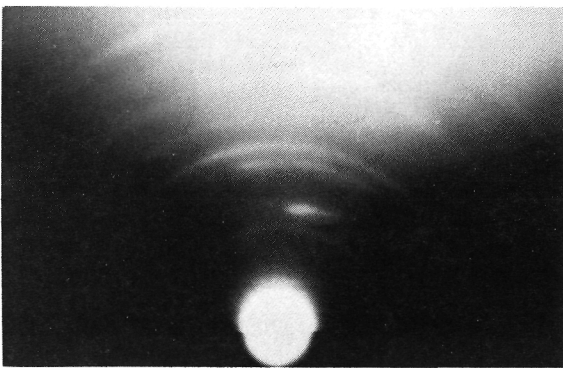


Figure 3. - Wear of head in sliding contact with various lapping tapes as function of sliding distance. Mn-Zn ferrite {110} plane; initial tape tension, 0.3 N; displacement of head,  $120 \pm 5 \mu\text{m}$ ; single pass sliding.

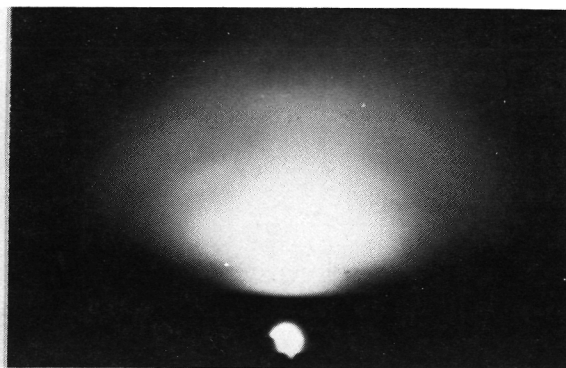
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(a) Replication electron micrograph.



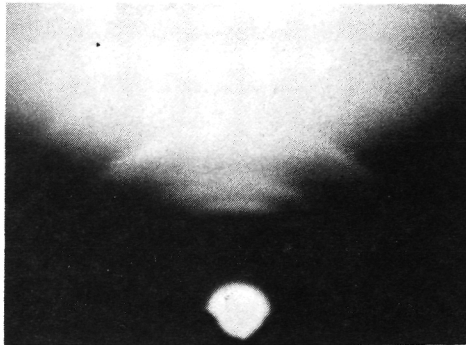
(b) Electron diffraction pattern; highly textured polycrystalline.



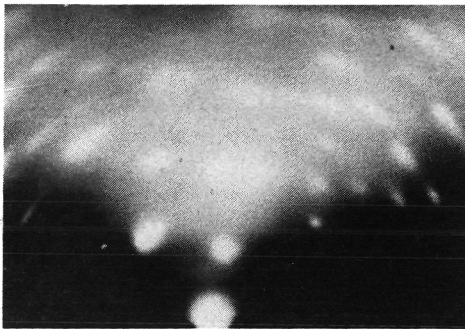
(c) Electron diffraction pattern; nearly amorphous.

Figure 4. - Wear surface of head in sliding contact with 14-μm  $\text{Al}_2\text{O}_3$  lapping tape (1000 mesh). Mn-Zn ferrite { 110 } plane; initial tape tension, 0.3 N; displacement of head,  $120 \pm 5 \mu\text{m}$ ; single-pass sliding.

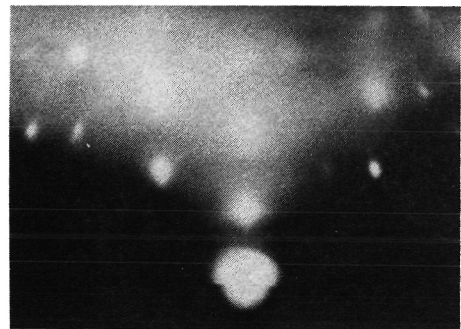
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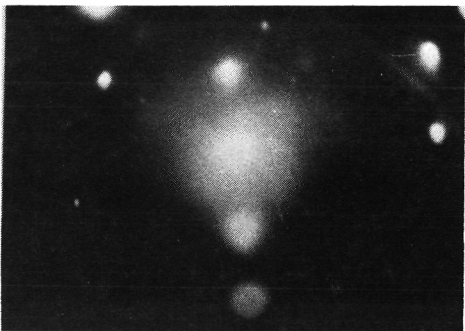
(a) Wear surface.



(b) Etched surface. Etching depth, 0.2  $\mu\text{m}$ .



(c) Etched surface. Etching depth, 0.4  $\mu\text{m}$ .



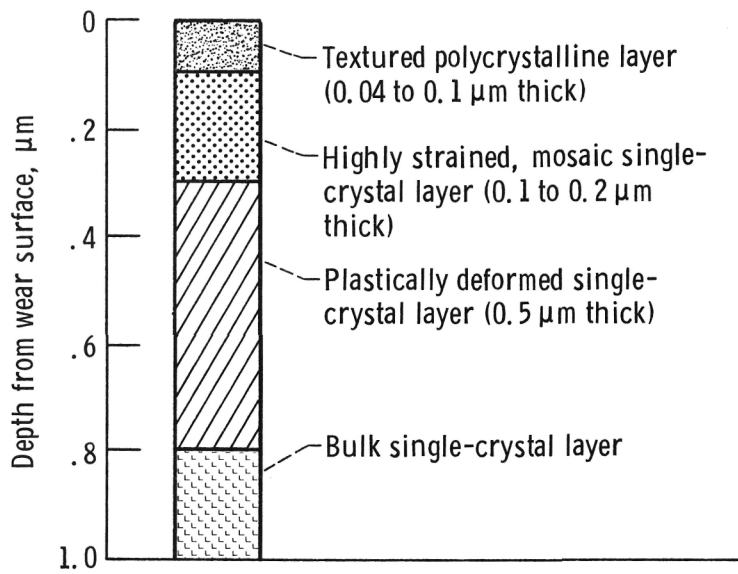
(d) Etched surface. Etching depth, 0.8  $\mu\text{m}$ .



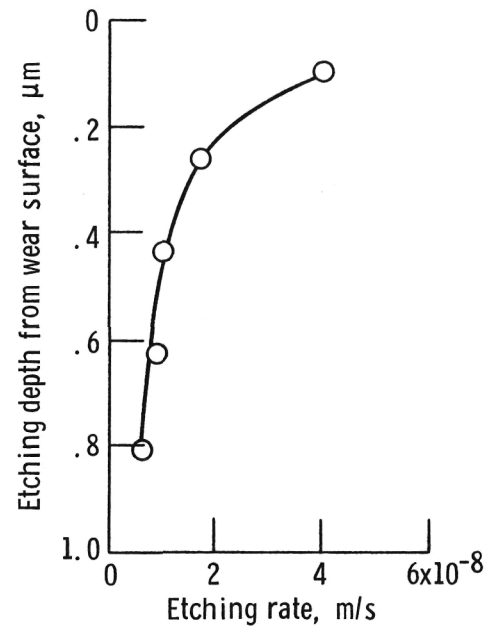
(e) Etched surface. Etching depth, 1  $\mu\text{m}$ .

Figure 5. - Deformed layer of head in sliding contact with 14- $\mu\text{m}$   $\text{Al}_2\text{O}_3$  lapping tape (1000 mesh). Mn-Zn ferrite {110} plane; initial tape tension, 0.3 N; displacement of head,  $120 \pm 5 \mu\text{m}$ ; single-pass sliding.





(a) Crystal structure of deformed layer.



(b) Etching rate as function of depth from wear surface.

Figure 6. - Crystal structure and etching rate of wear surface of head in sliding contact with 14- $\mu\text{m}$   $\text{Al}_2\text{O}_3$  lapping tape (1000 mesh). Mn-Zn ferrite {110} plane; initial tape tension, 0.3 N; displacement of head,  $120 \pm 5 \mu\text{m}$ ; single-pass sliding.

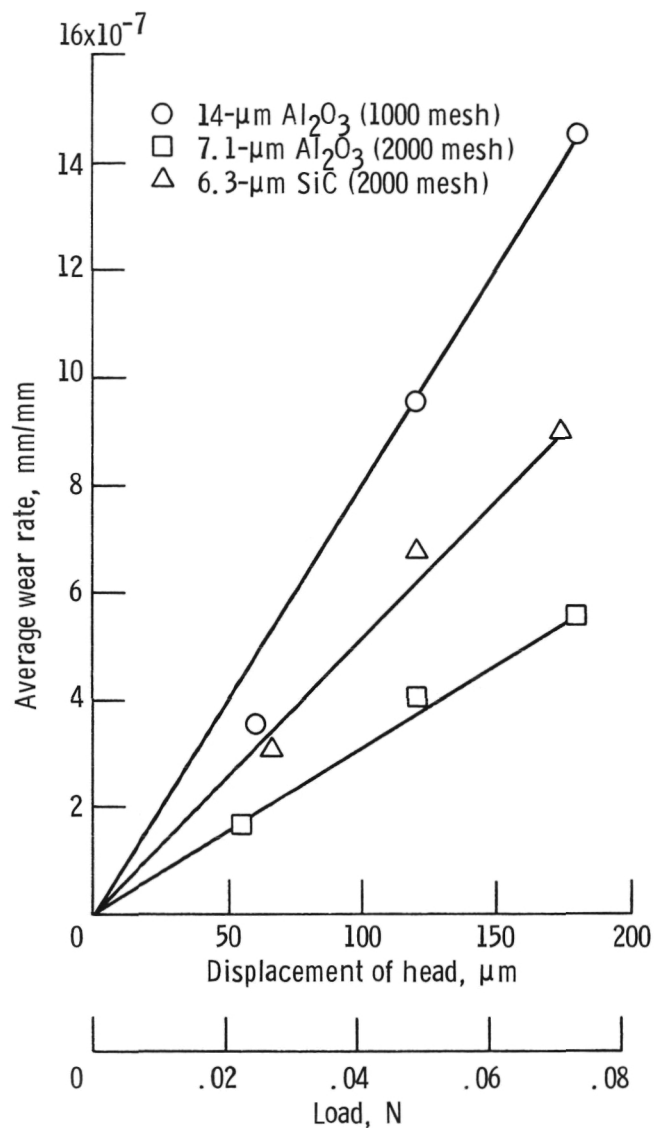
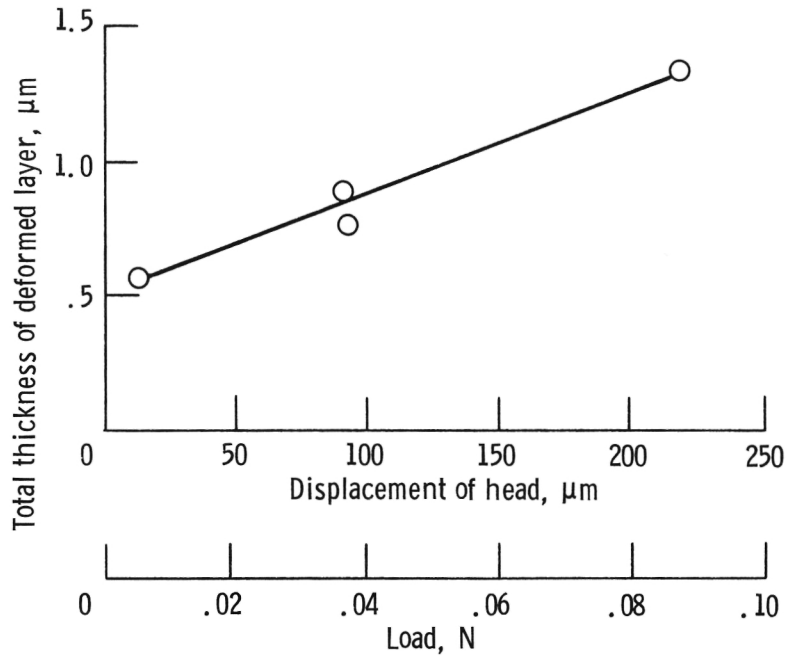
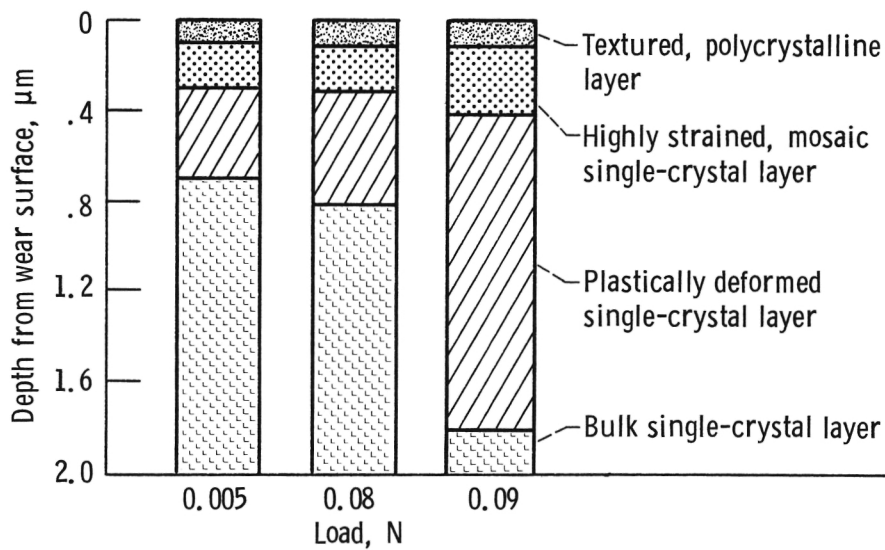


Figure 7. - Wear of head in sliding contact with various lapping tapes as function of normal load (displacement of head). Mn-Zn ferrite {110} plane; initial tape tension, 0.3 N; displacement of head,  $120 \pm 5 \mu\text{m}$ ; single-pass sliding.



(a) Thickness of deformed layer.



(b) Crystal structure of deformed layers.

Figure 8. - Deformed layer produced on head in sliding contact with  $14\text{-}\mu\text{m}$   $\text{Al}_2\text{O}_3$  lapping tape (1000 mesh) as function of normal load (displacement of head). Mn-Zn ferrite {110} plane; initial tape tension, 0.3 N; displacement of head,  $120 \pm 5 \mu\text{m}$ ; single-pass sliding.

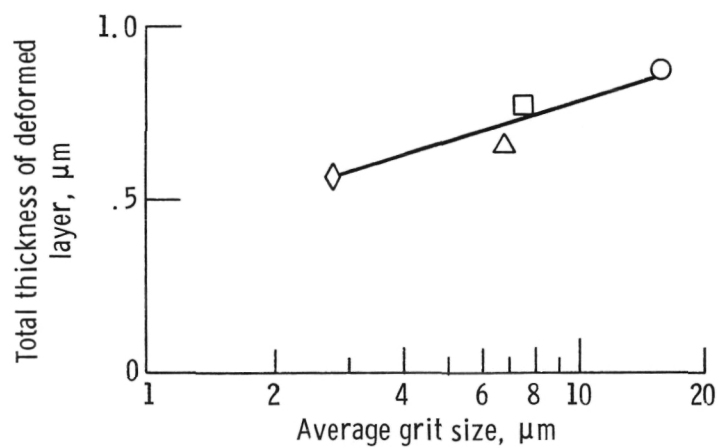
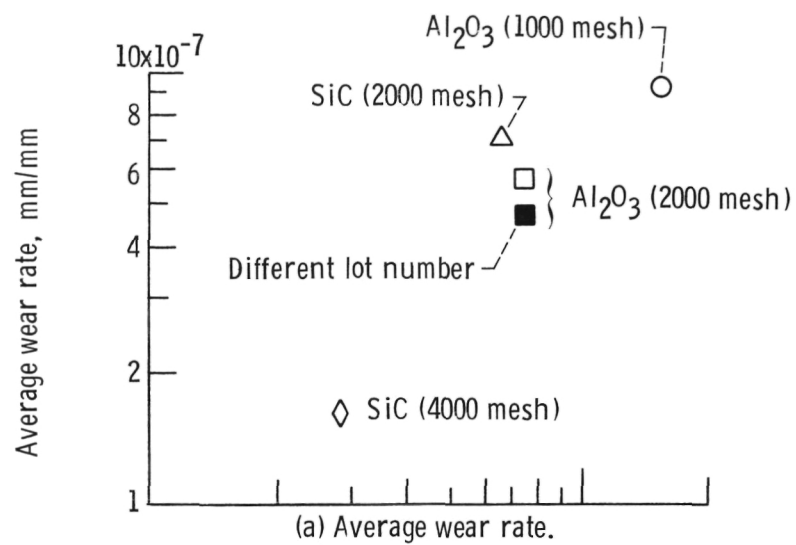


Figure 9. - Wear and deformed layer of head in sliding contact with various lapping tapes as function of abrasive grit size. Mn-Zn ferrite {110} plane; initial tape tension, 0.3 N; displacement of head,  $120 \pm 5 \mu\text{m}$ ; single-pass sliding.

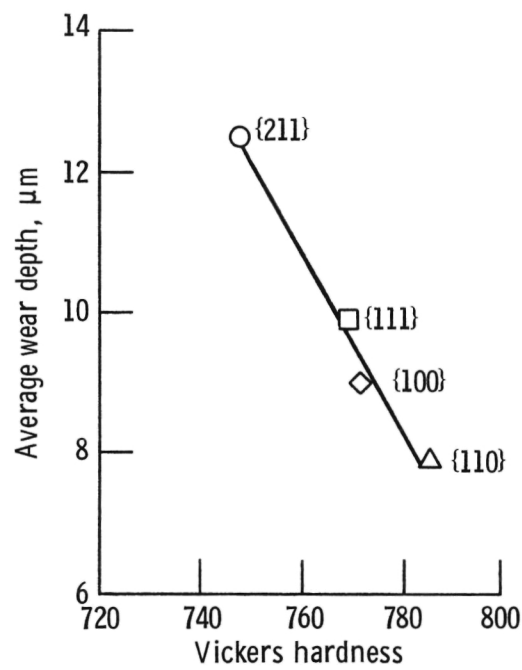


Figure 10. - Anisotropic wear for {100}, {110}, {111}, and {211} planes of Mn-Zn ferrite heads in sliding contact with  $7.1\text{-}\mu\text{m}$   $\text{Al}_2\text{O}_3$  lapping tape (2000 mesh). Sliding distance, 3.5 km; initial tape tension, 0.7 N; displacement of head,  $200\pm 5\text{ }\mu\text{m}$ ; number of passes, 60; Vickers hardness measuring load, 0.25 N.

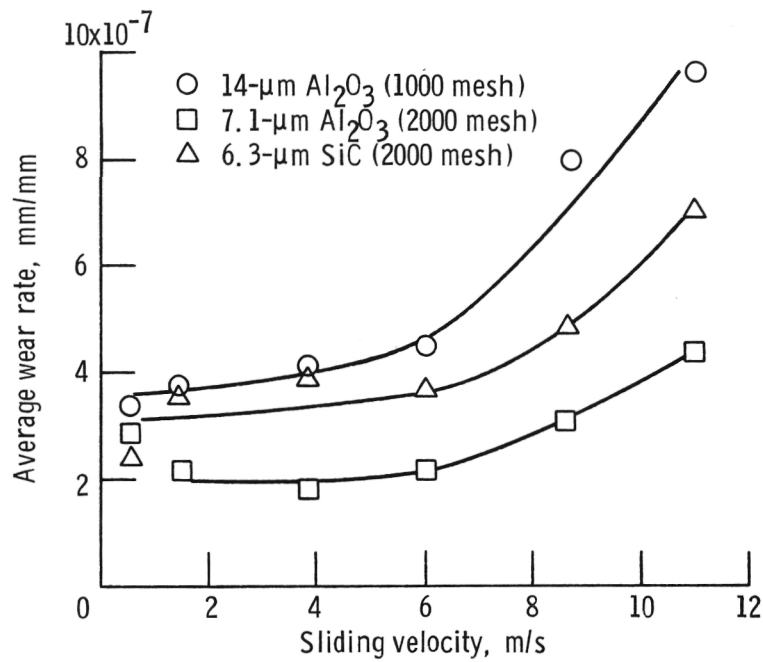


Figure 11. - Wear of head in sliding contact with various lapping tapes as function of sliding velocity. Mn-Zn ferrite {110} plane; initial tape tension, 0.3 N; displacement of head,  $120 \pm 5 \mu\text{m}$ ; single-pass sliding.

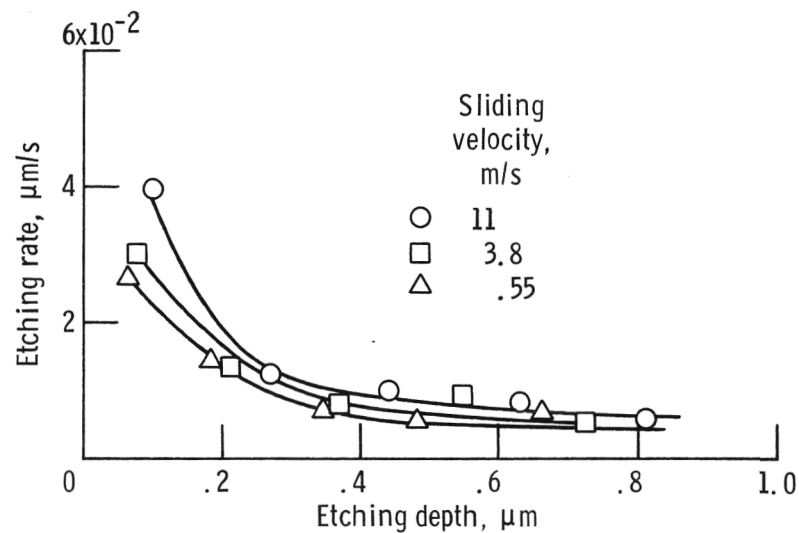


Figure 12. - Etching rate of wear surface of head in sliding contact with 14-μm Al<sub>2</sub>O<sub>3</sub> lapping tape (1000 mesh) as function of depth from the wear surface. Mn-Zn ferrite {110} plane; initial tape tension, 0.3 N; displacement of head,  $120 \pm 5 \mu\text{m}$ ; single-pass sliding.

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16. Abstract  <b>Wear experiments were conducted using replication electron microscopy and reflection electron diffraction to study abrasion and the deformed layers produced in single-crystal Mn-Zn ferrite simulated heads during contact with lapping tapes. The crystalline state of the head is changed drastically during the abrasion process. Crystalline states ranging from nearly amorphous to highly textured polycrystalline can be produced on the wear surface of a single-crystal Mn-Zn ferrite head. The total thickness of the deformed layer was approximately 0.8 <math>\mu</math>m. This thickness increased as the load and abrasive grit size increased. The anisotropic wear of the ferrite was found to be inversely proportional to the hardness of the wear surface. The wear was lower in the order {211} &gt; {111} &gt; {100} &gt; {110}. The wear of the ferrite increased markedly with an increase in sliding velocity and abrasive grit size.</b>					
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